Graduate Course in Antarctic Studies 2006/2007
Individual Report

# Ocular Damage in the Dry Antarctic Environment A Preliminary Study on Corneal Changes

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# Abstract

Epidemiological and experimental studies have confirmed that high levels of ultraviolet (UV) radiation a definite risk factor for certain types of cataract, with peak efficacy in the UV-B waveband. Over the last 20 years, circumpolar UV levels have increased, yet studies of ocular health have been limited to the Arctic regions. Low humidity in Antarctica may exacerbate this damaging environment for the eyes. Literature review in both ocular health and general medical journals has found that more data is critically needed before risk assessment can occur. In this preliminary investigation, enquiry into the incidence of ocular problems is made, and some conventional treatments are applied. There is further explanation regarding the impetus for emphasizing a study of corneal changes in this environment.

Measurements of UV radiation levels were conducted in Antarctica between December 2006 and January 2007, in order to investigate their relative intensities between the South Polar regions and Christchurch, New Zealand. Significantly increased levels of UV-A and UV-B radiation were measured,

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# 1. Introduction - Significance of the Project

Two issues underscore the need for undertaking studies of health risks of ultraviolet (UV) exposure to ocular structures. First, there is evidence of the depletion of the ozone layer and the reported consequent increase in ambient UV which will impact on various eye diseases. Second, an increasing number of people are working in Antarctica on a seasonal basis, therefore receiving significant cumulative exposure to UV.

On its own, low humidity causes mild ocular discomfort for most people in Antarctica. However, chronic exposure to dry environment coupled with intense UV exposure has not been assessed or monitored.

With advancing innovation and technology, Antarctic research is now more accessible than ever before. Therefore, studies on ocular health in extreme environments will prove to be both timely and relevant, for the understanding of ocular biomechanics.

# 2. Objectives

The primary purpose of this project is to design a pilot study to evaluate ocular health in the Antarctic environment. Data gathered will be used to help set up guidelines and recommendations for eye protection and management of common eye problems in Antarctica.

A range of ocular parameters will be monitored from the seasonal workers who stay primarily in the Scott Base area over the austral summer, and the results will be analyzed for change. Particular observation to corneal parameters is emphasized. The hypothesis of possible corneal changes as a result of being exposed to an environment of constant low humidity and high levels of UV radiation, is addressed.

### *2.1. Scope of Activity*

It is envisaged that measurements will take place both in Christchurch and Scott Base, spread over the four months of the typical working season in Antarctica. It is anticipated that 40-50 participants will be recruited. The intended design is a cohort study, with no intervention. The study will be carried out in three phases.

Preliminary assessment will be carried out in Christchurch to establish each subject's baseline. Monitoring examination will be made at Scott Base, towards the end of each subject's work contract, possibly in the final week of their stay in Antarctica. The final assessment will be carried out in Christchurch, a month after their return from Antarctica.

## 3. Background

### *3.1. Ultraviolet Radiation*

Increased levels of UV radiation (UVR) due to ozone depletion may have serious consequences for living organisms. A 10% reduction in ozone could lead to as much as a 15-20% increase in UV exposure depending on the biological process being considered. While the impact on human health, crop production, fisheries etc. is not fully understood, adverse effects of increased exposure to UV-B have been reported on plant growth, photosynthesis and disease resistance. The consequences of this added UV exposure are considered so serious that it was a major topic for discussion at the World Environment Conference, 2004.

For nearly twenty years, health authorities have recognized the risks associated with UV exposure. The World Health Organization (WHO), in collaboration with the United Nations Environment Programme (UNEP) and the International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA), published the first Environmental Health Criteria (EHC) monograph on Ultraviolet Radiation in 1979. At the United Nations Conference on the Environment and Development (UNCED) in 1992 it was declared under Agenda 21 that there should be activities on the effects of ultraviolet radiation. Specifically:

"(i) Undertake, as a matter of urgency, research on the effects on human health of the increasing ultraviolet radiation reaching the earth's surface as a consequence of depletion of the stratospheric ozone layer;

(ii) On the basis of the outcome of this research, consider taking appropriate remedial measures to mitigate the above-mentioned effects on human beings".

Every year since 1988, there have been large holes detected in the ozone during the austral spring over Antarctica (Roy et al., 1994). Indeed the average, global ozone level has decreased. Solar UV absorption by the atmosphere has been significantly reduced because of the depletion of the stratospheric ozone. Hence, living organisms, mammals and humans are now being exposed to higher intensities of UV, more than ever before. This provides an opportunity to study the effects of UVR on ocular structures. In Antarctica, this situation is magnified, yet human activity, such as research and tourism will continue to flourish on this continent. This underscores the current need to better identify the long-term ocular health risks of UV exposure.

### 3.1.A. Physical Characteristics of UVR

UV is one of the non-ionizing radiations in the electromagnetic spectrum and lies within the range of wavelengths 100 nm (which corresponds to a photon-energy of approximately 12eV) to 400 nm. The short wavelength limit of the UV region is often taken as the boundary between the ionizing radiation spectrum (wavelengths < 100 nm) and the non-ionizing radiation spectrum. In discussing UVR biological effects, the International Commission on Illumination (CIE) has divided the UV spectrum into three bands. The band 315 to 380–400 nm is designated as UV-A, 280 to 315 nm as UV-B, and 100 to 280 nm as UV-C (CIE 1987, 1999).

UV-induced biological effects depend on the wavelengths of the radiation. It is necessary for a proper determination of hazard to have spectral emission data. These consist of spectral irradiance (W m-2 nm-1) measurements or calculations of emissions from the source. The total irradiance (W/m2) is obtained by summing over all wavelengths emitted. The biological or hazard weighted irradiance (W/m2 effective) is determined by multiplying the spectral irradiance at each wavelength by the biological or hazard weighting factor (which quantifies the relative efficacy at each wavelength for causing the effect) and summing over all wavelengths. Such factors are obtained from action spectra.

### 3.1.B. Action Spectrum and Minimum Erythemal Dose

An action spectrum is a graph of the reciprocal of the radiant exposure required to produce the given effect at each wavelength. All the data in such curves are normalized to the datum at the most efficacious wavelength(s). By summing the biologically effective irradiance over the exposure period, the biologically effective radiant exposure (J/m2 effective) can be calculated. For UV induced erythema, the action spectrum is the minimum radiant exposure of UV at different wavelengths necessary to just cause erythema [adopted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), CIE, and the International Electrotechnical Commission (IEC)]. An example, for the near UV spectral region (315-400nm) UV-A, exposure to the eye should not exceed 1mW/cm2, for periods greater than 1000 seconds.

### 3.1.C. Understanding UVR Exposure

A number of national and international organizations have promulgated guidelines or standards on exposure to UV. Most are based upon the same basic criteria of the American Conference of Governmental Industrial Hygienists (ACGIH), the International Radiation Protection Association (IRPA) and International Commission on Non-Ionizing Radiation Protection (ICNIRP). According to their guideline, the basic exposure limit (EL) for both general public and occupational exposure to UV incident on the skin or eye is 30 J/m2(effective), when the spectral irradiance E(λ), at the eye or skin surface is mathematically weighted with the hazard relative spectral effectiveness factor S(λ) from 180 nm to 400 nm. For example, at 270 nm in the UV-C range, S(λ) is 1.0, but at 360 nm in the centre of the UV-A range, its value falls to 0.00013, and continues to fall for longer wavelengths.

The effective irradiance of a broadband source weighted against the peak of the spectral effectiveness curve (270 nm), is given as follows:

$$\mathrm{E(eff)} = \sum E(\lambda) \bullet S(\lambda) \bullet \Delta(\lambda)$$

where: Eeff = effective irradiance (W/m2)

E(λ) = spectral irradiance from measurements (W/m2nm)

S(λ) = relative spectral effectiveness factor (unit-less)

Δ(λ) = bandwidth of the calculation or measurement (nm)

The intensity of UV radiation is measured in the units of milliwatts per square centimeter (mW/cm2) which is energy per square centimeter received per second. Also, it is equivalent to the units of millijoules per square centimeter (mJ/cm2), which is energy received per unit area in a given time. For the UV-A, the total radiant exposure incident on the unprotected eye should not exceed $10^4$ J/m2 (1 J/cm2) within an 8 hour period. This was expressed in previous section as 1mW/cm2.

The limits apply to sources whose emissions are measured with an instrument having a cosine response detector oriented perpendicular to the most directly exposed surfaces of the body when assessing skin exposure and along (or parallel to) the line(s) of sight when assessing ocular exposure. Although no measurement averaging aperture is recommended, 1 mm is commonly used.

The permissible exposure duration, t(max), for exposure (in seconds) to UV is calculated by:

$$t(\mathrm{max}) = \frac{30}{E(eff)} \qquad \text{where } E(eff) \text{ is measured in (W/m2)}$$

Exposure duration is related to the effective irradiance, which means that it is wavelength specific. Examples are provided in Table 1.

| Duration of Exposure per Day | Eeff (μW/cm2) |
|---|---|
| 8 hr | 0.1 |
| 4 hr | 0.2 |
| 2 hr | 0.4 |
| 1 hr | 0.8 |
| 30 min | 1.7 |
| 15 min | 3.3 |
| 10 min | 5 |

| | |
|---|---|
| 5 min | 10 |
| 1 min | 50 |
| 30 s | 100 |
| 10 s | 300 |
| 1 s | 3,000 |
| 0.5 s | 6,000 |
| 0.1 s | 30,000 |

Table 1: Limiting UV exposure durations based on exposure limits (ICNIRP, 2004).

The EL's were developed considering lightly pigmented populations with greatest sensitivity and predisposition to adverse health effects from exposure to UV. The limits apply to UV exposure of the working population, but with some precaution also apply to the general public. In places like Antarctica, where the effective irradiance is significantly higher then in countries of lower latitudes, one can reach his/her exposure limit quickly in any one day.

### 3.1.D. Biological effects from UVR

There have been extensive dermatological studies on effects of solar radiation. Hence, a common description of solar radiance was derived from skin changes. The erythemal potential of an exposure to UV is the number of minimum erythemal doses (MEDs) represented by the exposure. An MED is the radiant exposure of UV that produces a just noticeable erythema on a previously unexposed skin. It corresponds to a radiant exposure of monochromatic radiation at the maximum spectral efficacy for erythema (around 300 nm) of approximately 150-2000 J/m2 (effective), depending on skin type. Usually, 200-300 J/m2 (effective) is used as the value of 1 MED for comparative safety purposes for white skin.

Studies on a cellular and molecular level have also been done in recent years. To produce any change, UV must be absorbed by the bio-molecule. This involves absorption of a single photon by the molecule and the production of an excited state in which one electron of the absorbing molecule is raised to a higher energy level. The primary products caused by UV exposure are generally reactive species or free radicals which form extremely quickly but which can produce effects that can last for hours, days or even years. DNA is the most critical target for damage by UV-B and UV-C radiations. While a considerable amount of knowledge is available concerning the interaction of UV with nucleic acids, controversy exists as to which lesion constitutes the most important type of pre-mutagenic damage. Cell death, chromosome changes, mutation and morphological transformations are observed after UV exposure of procaryotic and eucaryotic cells. Many different genes and several viruses (including HIV) are activated by UV exposure (Breuer-McHam, 2001). The genes activated by UV-B and UV-C are different from those activated by UV-A. Studies of DNA repair defective disorders have clearly established a link between UV induced DNA damage in skin and various types of cancer (Kowalczuk et al, 2006).

Solar UV has been shown to produce cancers in domestic and food animals. In experimental animals UV causes predominantly squamous cell carcinomas (SCC). UV-B is most effective at producing SCCs, although they are produced by UV-A, but at much higher intensities, similar to the levels needed for erythema and tanning. The effectiveness of UV-C is unknown except at one wavelength (254 nm). At this wavelength the effectiveness is less than UV-B. Many studies in experimental animals have demonstrated that UV exposure can cause both acute and delayed effects such as cataract, photokeratitis, damage to the corneal epithelium and various retinal effects. Studies of photochemical retinal injury in aphakic monkeys have shown that the retina is more vulnerable to photochemical damage from UV than the visible wavelengths (Li et al, 1990).

The three main types of UV radiation relate to health conditions differently, as depicted in the diagram below.

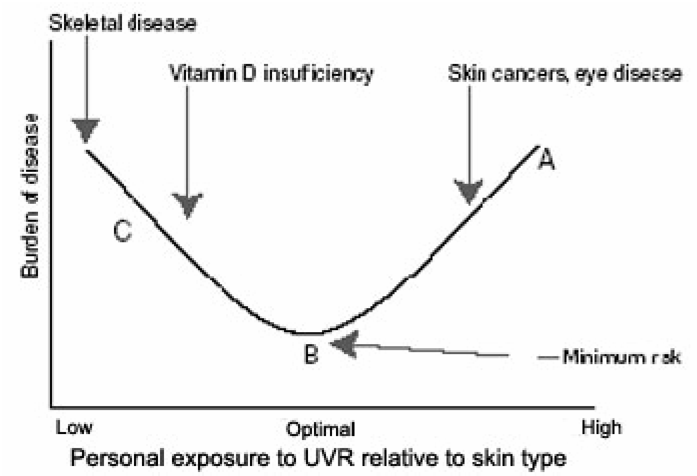

Figure 1: Relationship of UV exposure to burden of disease from WHO 2006.

With the objective of establishing public health policy, Lucas at al. from the World Health Organization has compiled the knowledge of the effects of UV radiation, and related effects with disease burden (2006).

### 3.1.E. Health Effects on Humans Eyes

The following descriptions of eye conditions provide impetus for studying health effects of solar radiation. The conditions are discussed in the context of exposure to UVR, Since published studies in Antarctica are limited, the literature review in this section draws from studies of eye conditions at lower latitude, but with high UVR.

*Hyperkeratosis, carcinoma-in-situ, and squamous cell carcinoma of the conjunctiva*

These conditions develop gradually and cannot necessarily be distinguished clinically as a direct result of UV radiation over a particular length of time. Specialists agree that cancerous tumour like actinic keratosis, is induced from UV radiation. Invasive SCC is often said to arise from a pre-cancerous lesion. Epidemiological studies indicate that these tumours appear several decades after initial UV exposure. Over 90% of SCCs contain a UV-like mutation in a type of suppressor gene (Brash et al, 1996). After the initiation of this suppressor gene, UV exposure in later years seems to promote these pre-cancerous lesions to become actinic keratosis.

Approximately 5% to 10% of all skin cancers occur in the eyelid. Incidence study in Minnesota, USA (Cook and Bartley, 1999) indicates that basal cell carcinoma is the most frequent malignant eyelid tumor, followed by SCCs, sebaceous gland carcinoma, and malignant melanoma. UVR damage is also linked with rare inherited syndromes. Xeroderma pigmentosum is a recessively inherited syndrome characterized by clinical and cellular hypersensitivity to solar radiation and a defect in the capacity to repair UV-induced damage in DNA (Clement et al, 2006).

Epidemiological studies worldwide revealed a correlation between the increase of skin cancer incidence and UV exposure in Caucasians. An Australian study looked at the incidence and mortality from melanoma, in relation to latitude (Jones et al, 1992). Between 1982 and 1987 the male:female incidence ratio in high latitudes in the Southern Hemisphere, showed that there was a proportional association between high latitude and melanoma incidence rate. A surveillance of skin cancers incidence in Southern Chile between 1987-2000, found a general increase in all types of skin cancers (Abarca and Casiccia, 2002). This illustrates the effect of exposure to a higher level solar UV, causing a greater effectiveness for erythema and photocarcinogenesis in the eye adnexa.

Ocular surface squamous neoplasia (OSSN) encompasses the conditions of simple dysplasia to carcinoma in situ to invasive SCCs. Although rare, it is directly associated with UV exposure (Lee and Hirst, 1997).

*Photokeratitis and photoconjunctivitis*

Cases of photokeratitis and photoconjunctivitis have occurred between 0.5 and 24 hours after prolonged exposure to intense solar radiation, often in highly reflective environments, as first reported by Wittenberg (1986). The most severe cases are usually manifested as snow blindness, suggesting that UV is the cause of this condition.

The cornea is very effective in protecting the eye from UV-B. Different ocular structures block the different types of UVR, as illustrated in Figure 2.

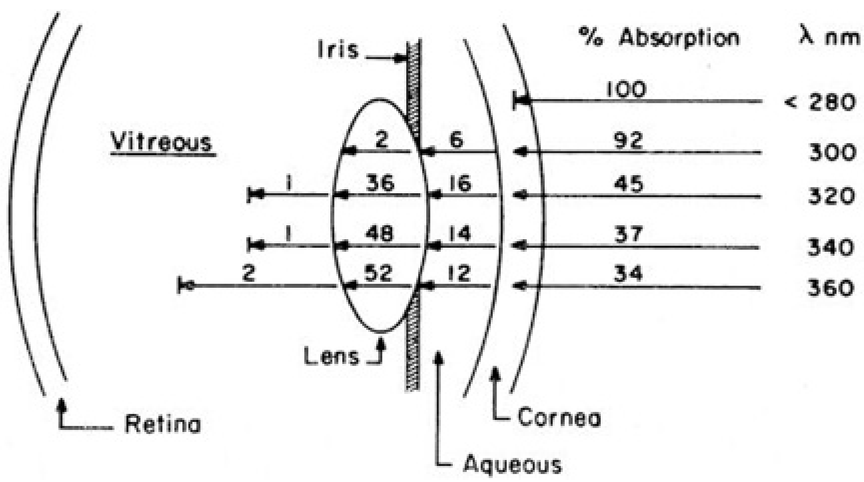


Figure 2: UV penetrance in a normal phakic eye.

The action spectra for human were first estimated by Pitts (1973) in a series of laboratory studies. He found the mean threshold of UV-B (290-315 nm) for photokeratitis at 3500 J/m2. It is estimated that 100 to 200 seconds of direct, unattenuated exposure to 295-315 nm solar radiation will result in photokeratitis (Pitts et al, 1987). Blotting out the solar disc would remove around 40% of the UV, still leaving a threshold of around 5.5 minutes. Sliney (1986) has estimated that the reflected levels of UV from light sand should be sufficient to cause a threshold photokeratitis within exposure periods of 6-8 hours centred around midday, and within 1 hour for UV reflected from snow.

Studies over the last two decade have indicated that exposure to UV radiation of the cornea is more damaging than was previously thought. It had been known for many years that the outer epithelial layer was the region most damaged by UV radiation. Pitts et al, (1987) have shown that the endothelial layer in the primate cornea is also damaged (specifically by UVB of wavelength 300nm) and this, unlike the epithelial damage, is permanent.

### *Pinguecula*

Pinguecula is a fibro-fatty degeneration of the interpalpebral conjunctiva. The pathological changes that occur in pinguecula are similar to actinic elastosis of the skin, a condition thought to be linked to sunlight exposure. This indirect evidence suggests that exposure to sunlight may be a risk factor for pinguecula.

Geographical variation in the occurrence of pinguecula has been reported, with higher prevalence in Arabs living near the Red Sea than in Eskimos from Greenland or Caucasians in Copenhagen (Norn, 1982). Johnson (1981) in a study of pinguecula in Labrador found the size of pinguecula was correlated with the severity of climatic droplet keratopathy. Of the proposed environmental causative agents, only ultraviolet radiation, reflected from ice and snow, explains the distribution of the disease. However, Taylor *et al.* (1989) in the study of Chesapeake Bay watermen found a weak association for the presence or absence of pinguecula with exposure to UV-A and UV-B. It is concluded that there is currently insufficient epidemiological or experimental data for an assessment of the risk of pinguecula with exposure to UV.

*Pterygium*

Pterygium is a triangular shaped degeneration and hyperplastic process in which the bulbar conjunctiva encroaches on the cornea. A geographical association between variation in the occurrence of pterygium and variation in sunlight exposure was first suggested by Talbot in 1948. On the basis of recent studies in Jordan, with high UV irradiance because of proximity to the equator, accumulated exposure to sunlight influences the development of pterygia in human populations (Al-Bdour and Al-Latayfeh, 2004).

Association with place of residence has been made with the incidence of pterygium. Many studies over the past four decades have confirmed the global pattern, that pterygium has an inverse gradient with latitude. Data from Canada indicates that pterygium is also common in arctic and sub-arctic environments (Johnson 1981). In 1989, Taylor et al. investigated the association between exposure to UV radiation and corneal disease, in 838 watermen who work on the Chesapeake Bay, Maryland. Their results showed that pterygium and climatic droplet keratopathy were significantly associated with a broad band of UV radiation exposure, but the association with pinguecula was weaker.

Mackenzie et al. (1992) undertook a hospital-based case-control study of pterygium in Queensland. A strong dose-response relationship was found with closeness of place of residence to the equator, type of outdoor work environment (e.g. sandy) and amount of time spend outdoors. The most striking finding was the magnitude of risk associated with spending most of the time outdoors was stronger when related to childhood exposure. The risk associated with working at ages 20-29 in an outdoors environment of mainly sand or concrete was associated with a relative risk of 11.3 compared with indoor workers.

*Climatic droplet keratopathy*

Climatic droplet keratopathy is a degenerative condition usually affecting both eyes symmetrically, and restricted to the exposed interpalpebral band of the cornea. This condition occurs throughout the world, but is more common in areas with snowfall persisting late into the summer in the northern hemisphere, such as parts of northern Canada, Siberia and Mongolia, and in areas of sand and desert in other latitudes, including Somalia, the Arabian peninsula, Iran, and Australia. Johnson (1981) reported a geographical correlation with the calculated flux of reflected UV from snow and ice throughout the year in the eastern coast of Newfoundland and Labrador and the eastern Arctic of Canada.

In a cross-sectional study of Chesapeake Bay waterman study, Taylor et al. (1989) examined the risk of climatic droplet keratopathy with chronic UV-B exposure. Although a positive association was found for those in the highest quarter of exposure compared to those with the bottom quarter, further analyses of this data (Taylor et al., 1994) showed the risk of climatic droplet keratopathy was also related to UV-A.

Since 1994 there have been few original research reports on the association between UVR and climatic droplet keratopathy. There is strong evidence that this type of corneal degeneration is due to environmental factors. Other proposed aetiological agents such as low atmospheric humidity, low temperature or high temperature have been excluded. It is possible that particulate injury by wind-blown ice or snow or sand particles may contribute to the photochemical degradation of the limbal area from UV radiation. This inflammation causes outpouring of additional plasma proteins from the blood vessels of the corneal limbus. Reflected UVR (eg from snow, white sand or water) may be more important than direct sunlight (Sliney, 1994).

*Cataracts*

Cataracts may be a more widespread health effect of UV-B radiation than skin cancers, because all populations will be affected. A cataract occurs when the normally translucent lens of the eye becomes cloudy and scatters light so that vision is impaired. Exactly how the ordered crystalline proteins of the lens become denatured, causing a cataract, is still uncertain. The lens proteins contain amino acids, such as tryptophane, which are susceptible to photo-oxidation by oxygen free radicals generated by UV-B. It is believed that the oxidized lens proteins become structurally altered.

Studies of fishermen and others engaged in gathering seafood in Chesapeake Bay, who were exposed not only to direct solar radiation but also to its reflection from the ocean surface, showed a higher incidence of cataracts than did a control group who worked entirely indoors (Taylor et al, 1989). Fortunately, wearing glasses or sunglasses is sufficient to block much of the ultraviolet radiation that causes cataracts (Rosenthal et al., 1988). Plastic lenses, whether tinted or clear, reduce ocular exposure by more than 90%. Hats as well as protective eyewear provide major protection. Logistic regression analysis controlling for age showed a strong correlation between cumulative UV-B exposure and cataract. This analysis indicated that a doubling of UV-B exposure will increase the risk of developing cataracts by 60%. Conversely, if the ocular exposure to UV-B is halved, the risk is reduced by 40%. Since ozone levels is inversely proportional to the amount of UV-B, computational models have predicted that a 10% decrease in stratospheric ozone could cause an additional 1.6 and 1.75 million more cases of cataracts worldwide every year (Chiang et al, 2006). D.H. Sliney's (1995) study of ocular exposure to environmental sunlight, has demonstrated that it is difficult to determine accurately the level of solar UVR exposure of the human eye.

*Diseases of the Choroid and Retina*

Among adults, only small amounts of UV-A and UV-B at wavelengths below 380 nm reach the retina, because of the very strong absorption by the cornea and lens, see Figure 2. Less than 1% of radiation below 340 nm and 2% of radiation between 340 and 360 nm reaches the retina (Barker and Brainard, 1993). Even so, the retina is highly sensitive to light, and damage to the human retina can be seen even years after a single exposure to the macula of relatively low intensity short-wavelength light. Development and exacerbation of AMD can occur because of chronic exposure to visible blue light and UV-A.

Exposure to the sun, particularly deliberate staring, can cause solar retinopathy, with clearly defined macular lesions. A macular hole may occur with oedema to a wide area. Yanuzzi et al. (1987) found an increased incidence of solar retinitis in areas of ozone depletion. In general, retinal exposures are difficult to quantify because of problems in determining the size of the retinal image and the ocular transmittance for UV radiation. Retinal detachments have a tendency to occur more commonly in spring and summer than in winter (Paavola et al, 1983) for inhabitants of higher latitudes (greater than 60°N) in the northern hemisphere.

The pattern and incidence of UV damage to the eye are different in Antarctica, where intense light and UV push the eye to a limit. In a review of ocular risks by UV exposure, Meyer-Rochow (2000) emphasized the need for international effort to quantify the risks in the Antarctic and Arctic regions.

## *3.2. Low humidity*

With an average rainfall of about 2 inches per year, Antarctica has very low average humidity. Low humidity causes discomfort for people living in Antarctica, from dehydration, to the hazards of building up static electricity. While people are conscious of increasing fluid intake and using moisturizing agents for skin, they are less equipped with the amelioration of ocular discomfort.

Dry climatic conditions may cause objective changes to the cornea, not only subjective symptoms, like grittiness. Erdelyi et al (2007) carried out a study on morphological corneal properties in dry eye, using confocal laser scanning microscopy of the cornea, in vivo. Results showed that dry eye patients had significant alterations in the cornea, and suggested that they were due to increased desquamation of the superficial cell layer.

In 1999, Liu and Pflugfelder used the Bausch and Lomb, Orbscan corneal topography system, to study corneal thickness. Corneal thickness was found to be statistically lower in dry eye patients than in normal eyes. They postulated that long-term dryness and immune activation may decrease corneal thickness. As corneal topography became more accessible in clinical practice, it provided another parameter for examination of dry eyes. Corneal surface irregularity was higher in patients with aqueous deficiency (Liu and Pflugfelder, 1999). Surface irregularities may contribute to glare disability, which would compound existing visual difficulties that an Antarctic personnel has to face.

An interesting case was recorded of corneal topographic change after exposure to Arctic conditions. The patient had bilateral laser in situ keratomileusis and went trekking near the North Pole, eight weeks post-operatively. It was proposed that the myopic change to the cornea was attributed to biomechanical changes that may have been induced by corneal dehydration in the Arctic environment (Fam et al, 2005).

# 4. Preliminary Investigation - summer of 2006/2007

The multi-disciplinary perspective of the Graduate Course in Antarctic Studies has provided an opening to my investigation on ocular health in Antarctica. As part of the commitment of this course, students had to complete a set of Antarctic field projects. From this experience, I collected informal reports of ocular discomforts from fellow students, and more importantly from workers who would spend 3-4 months in Antarctica. However, because of this commitment, there was little time to recruit subjects. Collection of subjective data from volunteered staff members was made at Scott Base. The subjects were recruited based on reports of dry eyes symptoms, such as hyperaemia, grittiness and burning sensations. Ten subjects were recruited, 2 of whom were GCAS students.

## *4.1. Prevalence of Dry Eyes Symptoms*

In this initial investigation, the subjects filled out a dry eye questionnaire (see Appendix I). Their typical working environments were also noted. For treatment of symptoms, they were given the choice of sample lubricating drops and/or take a session with the moisture-chamber goggle. There were a total of twelve participants, two of whom were fellow students in the GCAS course. The GCAS course spent 16 days in Antarctica, therefore their eyes were exposed to this environment for a much shorter time compared to Scott Base personnel.

*Lubricating eye-drops.*

Sample eye-drops, Bion Tears were donated from Alcon Laboratories P/L. Subjects were given two packs of single-use Bion Tears, to use as required, over the following 10 days. Their response to eyes drops, after the 10days were recorded. (The

GCAS group was away from Scott Base for 10 days which made it difficult to recruit more people.)

*Therapy with moisture-chamber goggles.*

Subjects wore a pair of moisture-chamber goggles, fitted to cover the eyes and eyelids for 10 minutes. Prior to wear, a custom-made cotton ringed-pad was wetted with saline solution, inserted into the inner rim of the goggles, and the unit was warmed. Once worn, the goggles provided humidified air around the eyes. The humidity optimizes heat transfer to the skin of the lids, thereby stimulating secretion from Meibomian glands. While subjects were using the goggles, their vision was unobstructed, allowing them to do sedentary tasks, such as reading.

All responses were positive relief of dry eye symptoms, and an expressed desire to have some treatment options available on base.

For the dry eye survey, some of my findings were:

- All subjects had experienced grittiness and burning sensations at a regular frequency.
- Six subjects had experienced intermittent blur at the same time that their eyes felt uncomfortable.
- Four subjects used lubricating on a regular basis.

My investigation included a search of Scott Base's first-aid record for eye incidents. For most seasons, the occurrence of photokeratitis was very low, and most ocular incidents were work-related accidents, such as fluid-sprays from mechanical work. Blunt injury was a common result from slipping on ice, and subsequent bruising of eye adnexa. The first-aider informed me that most staff members experienced some ocular discomfort but individuals were responsible for supplying their own eyedrops. This contrasted with other non-prescription medications that were supplied at no cost as part of first-aid.

## *4.2. Measurement of Incident Dose of UVR*

UV radiation was measured by using a Spectroline DRC-100X Digital Radiometer with three sensors DIX254, DIX300 and DIX365, sensitive to UV light of 245nm (UV-C), 300nm (UV-B) and 365nm (UV-A) wavelength respectively. The detailed relative response curves of these sensors are given in Figure 4 in Appendix III.

Additionally, two UV-filters were used in combination with each of the sensors. The Corning 7-54 filter appears black and the Corning 7-59 filter appears purple. They are referred to as Fa and Fb respectively. The filters are specific to a certain narrow bandwidth, hence the transmittance measured from the filter and sensor combination would ensure more precision in the wavelength being measured. Their transmittance functions are given in Figure 3 in Appendix III. The eyewear, goggles (made by SCOTT) and sunglasses (made by UVEX) issued by Ant. NZ were also tested for transmittance, by measuring in combination with each of the sensors.

Measurements were made at times when the student investigators were not working on other assigned projects. Therefore, the UV readings were not taken at a consistent time of day.

The measurements indicated that on a clear-day comparison, the levels of UV-B were similar between Christchurch (latitude 43°S) and the snow-covered campsite (latitude 77.7°S). While on an overcast-day, the levels of UV-B on a snow-covered terrain were typically 3-4 times the level on Christchurch's cloudy day. Higher UV-B levels were presumably the result of increased light scattering in the atmosphere. In Antarctica, weather conditions are frequently overcast, therefore chronic high levels of UV-B will be expected.

UV-A level was also higher at the snow-covered terrain of the GCAS campsite in Antarctica, than in Christchurch. However, the level was comparable between Christchurch and Scott Base, which has low reflectance off the ground, given that it is a barren dusty, patch of snow-free area.

The relative transmittance of filters was an exercise to check that the sensors were indeed wavelength specific.

Results of light transmittance through the sunglasses and goggles indicate that these eyewear are adequate for the purpose and Antarctic environment.

## 5. Method and Materials

The pilot study will set up a register of ocular assessments, with emphasis on corneal parameters, corneal thickness (pachymetry) and topography. The study is observational in nature, but may extend to a full, controlled scientific model if resources allow. It will rely on recruitment of all Scott Base workers over an austral season, which can be 40 to 50 subjects.

A. Ethics approval will be applied for, via the University of Canterbury's Human Ethics Committee.

B. Research support and approval will be applied from Antarctica New Zealand. All science programmes involving Antarctic are partially funded by this organization. Scott Base personnel are staff members of Antarctic New Zealand, therefore subject recruitment will be directly linked with Antarctica New Zealand.

C. Measurements of UV and humidity will be obtainable from Scott Base weather monitoring station. These form the independent variables of the study.

D. Each subject will be assessed on the nature of their UV exposure and the average level of humidity in the environment of their work.

E. Two large pieces of equipment will need to be acquired and taken to Antarctica, for the continuing eye assessments: corneal topographer and pachymeter. The environment in which the machines will operate at Scott Base, would be similar to standard office condition in New Zealand. Examinations would be carried out in the room that is currently designated for first-aid purposes. For biomicroscopy, the investigator would have to examine the subjects at McMurdo Station's medical clinic, as they have the only biomicroscope.

F. Ocular examinations will be carried out by a single optometrist-observer/investigator.

*Stage 1*

Prior to departure, all Antarctic personnel converges in Christchurch for final procedures, such as clothing assignment. The first phase of the study will be an eye examination to be conducted, in a pre-determined ophthalmic/optometric practice in Christchurch. Full eye examination for Antarctic personnel shall include:

- Ocular history and general health
- Visual acuity - unaided and corrected
- Refraction
- Biomicroscopy
- Corneal topography
- Corneal pachymetry

- Intraocular pressure
- Ophthalmoscopy – dilated examination

These records will be the dependent variables of the study.

*Stage 2*

The same set of dependent variables will be measured towards the last week of the subject's stay at Scott Base. Careful note of ocular history will be important, to determine the prevalence of dry eye symptoms.

*Stage 3*

A month after their return to New Zealand, the same set of measurements will be made, preferably by the same investigator, with the same equipment. If the subjects reside out of Christchurch, then the assessment will be conducted by their local eye care practitioner.

## 6. Discussion

Very little study has been done regarding ocular health in the Antarctic and Arctic regions. In the past, Antarctic research has mainly concentrated on "science of discovery", and it is just beginning to be realized as a natural laboratory for monitoring physiological phenomena, both in human and in animals.

The subject of dry eyes has not been adequately addressed in Antarctica. Discussion with the first-aider, who is the base nurse/paramedic, revealed that ocular discomfort is under-reported, with most people choosing to ignore the symptoms, despite visible signs of hyperaemia. Instigating an objective measure, such as corneal examination with biomicroscopy would give clinical evidence in this matter.

In the preliminary exercise of information gathering, it was difficult to co-ordinate meeting time with Scott Base staff. The GCAS programme had its schedule which took time away from the base, and the base staff had work schedule that did not always fit into examination time. This is the reason for the small sample of subjective data collected. Ideally, the investigator should spend 10-15 minutes with a subject in the future pilot study. Assuming that all Scott Base personnel will take part in the study, the investigator would need to spend a week at Scott Base, in order to carry out the assessment.

Data of UV irradiance of the Scott Base area, over the austral summer can be obtained from an outside source, National Institute of Water and Atmospheric Research, since it would be more accurate. During the GCAS field trip, the UV measurement was performed in order for us to gain insight at the variability of this atmospheric entity.

The two parameters, pachymetry and corneal topography are chosen because the findings from recent corneal studies show that the corneal is a responsive and dynamic structure. If corneal thickness does decrease significantly in dry environment, for extended period such as over an austral season, then there may be a cumulative damage to the eye's natural filter from UV. Given that UV levels are consistently high in Antarctica, a compromised cornea may give rise to more acute corneal changes, such as higher incidence of photokeratitis.

In the reported case of corneal changes after LASIK procedure (Fam et al., 2005), it highlights the unknown limits of corneal structural integrity, when exposed to unusual climatic conditions. With the preponderance of people undergoing corneal refractive procedures, there will be a higher proportion of Antarctic personnel whose eyes will be tested in conditions of low humidity.

### *6.1. Case Studies*

A secondary objective of this study is to draw up case studies, such as making detailed observations of sub-groups like: post-LASIK patients, and those who take medication that increases their susceptibility to photo-toxicity.

To assess potential hazards, we can not consider just the optical and radiometric parameters of the optical source in question, but also the geometrical exposure factors. Subject's location of work, such as snow/ice surfaces or ground dirt surfaces, influences the effective amount of UV radiation reaching the eyes. As previous researchers have concluded, personal UV dosimetry showed that the occupation was important in determining daily exposures. Scientists in the field received an approximately two-fold higher dose than individuals, such as medics and computer scientists, who spent the majority of their time in tents. I would prefer that subjects wear personal UV dosimeters to measure the true exposure. This extra dimension of measurement would depend on availability of resources.

### *6.2. Costs*

Science is Antarctica is expensive. The biggest cost in this study would be the insurance to cover the transport of equipment to Scott Base. Although the equipment is operated in normal office conditions, the period in transit may expose the equipment to extreme cold. Specifications of equipment would have to be thoroughly checked. Other costs include the use of an optometric/ophthalmic examination room, and general materials use for research.

The ocular assessments of subjects would proceed easily because the subjects have one central location, Christchurch, at which to report before their departure to ice. However, subjects who do not live in Christchurch may have to organize a visit to another local optometrist/ophthalmologist practice for the final assessment. This problem with this is the inconsistency of data from different equipment. Subject attrition rate may increase as well.

### *6.3. Other considerations*

Cataracts are a long-term change that would not be monitored in this study. Renewal of interest in this subject is valid, given that previous research is more than 10 years old. Ideally, a multi-centre, long-term clinical study can be conducted, involving other bases in other Antarctic regions. With better imaging system available nowadays, one can use a more precise objective method of examination, such as light scattering through the media. A population of relatively young pseudophakes may still be involved in Antarctic field work. This opens another area of study for the risk of UV damage to the retina, and the effectiveness of implants with UV-filters.

## 7. Conclusions

Despite the accumulation of scientific evidence to indicate that chronic UV exposure may accelerate ageing processes in ocular tissues, the quantitative question of "How much is safe?" remains to be answered conclusively. This reason for this is largely due to limited research in the area of extreme exposure.

The pilot study will address the issues of the ocular effects of low humidity and high UV irradiance. To date, full assessment of ocular health has not been performed for Antarctic workers, so this would help set up guidelines for ocular safety. In order to assess potential hazards, one must not only consider the optical and radiometric parameters of the optical source in question, but also the geometrical exposure factors.  This knowledge is required to determine accurately the irradiances (dose rates) to exposed tissues.

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# Appendices

## *Appendix I: Moisture-chamber goggles*

This is a novel device, which delivers heat therapy at lower temperature, to generate a volume of humidified warmed air to bath the eyes and eyelids. The moist air preserves lid function by promoting lipid release. It enhances normal tear function naturally, increasing patient comfort without the risk of pharmacological toxicity.

The moisture-chamber device was designed by an ophthalmologist (UK) J.R. Fuller, and developed by his brother, E.T. Fuller who is an engineer based in New Zealand. Several prototypes have been made before the product was sold to Laboratoires Théa, France, for production.

Recently two devices from Japan and one from the UK have been introduced but they lack essential safety and efficacy features of our device. The devices from Japan and the UK require the eyes to be closed during therapy. Crucially, this moisture-chamber device incorporates an anti-condensation mechanism in the lens design, so that the patient can see normally during the treatment. The patient can continue with sedentary activities during treatment, which could be for five to ten minutes two or three times a day. Two different prototypes are in use and there have been published randomized masked controlled clinical trials in peer-reviewed journals to demonstrate safety and efficacy.

The pair of goggles is worn over the eyes like a standard pair of swimming goggles. The goggle-unit is attached to an AC supply, which powers the heater. Temperature is pre-warmed to 50°C, and the unit maintains this temperature through out the therapeutic session of 10minutes. The lenses are double glazed with the anti-condensation mechanism, therefore are resistant to fogging.

## *Appendix II: Dry Eye Questionnaire*

(page 1)

Name: ________________
Date: ________________

Please fill in the blank or circle the answer that best describes you. Choose only one answer per question.

1. What is your age? __________

2. What is your gender?

**1** Male
**2** Female

3. Have you worn contact lenses in the past?
**1** Yes
**2** No

4. If you have worn contact lenses in the past, which of the following did you wear most recently?

| | Yes | No | Not applicable |
|---|---|---|---|
| a. Rigid gas permeable ........................................................ | **1** | **2** | **0** |
| b. Disposable (lenses replaced frequently) .................................... | **1** | **2** | **0** |
| c. Soft daily wear (lenses replaced after 1 year or longer) ……......…. | **1** | **2** | **0** |
| d. Extended wear (lenses worn overnight) ...................................... | **1** | **2** | **0** |

5. Questions about **EYE DISCOMFORT**:
During a typical day in the past week, **how often** did your eyes feel discomfort?
**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

6. Questions about **EYE DRYNESS**:
During a typical day in the past week, **how often** did your eyes feel dry?
**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

7. Questions about **EYE GRITTINESS AND SCRATCHINESS**:
During a typical day in the past week, **how often** did your eyes feel gritty and scratchy?
**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently

**4** Constantly

(page 2)

8. Questions about **EYE BURNING AND STINGING:**

During a typical day in the past week, **how often** did your eyes feel burning and stinging?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

9. Questions about **CHANGEABLE, BLURRY VISION:**

During a typical day in the past week, how often did your vision change between clear and blurry or foggy?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

10. Question about **EYELID REDNESS:**

During a typical day in the past week, **how often** did your eyelid margins look red?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

11. Question about **WATERY EYES:**

During a typical day in the past week, **how often** did your eyes look or feel excessively watery?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

12. Question about **EYE MUCUS AND CRUSTING:**

During a typical day in the past week, **how often** was mucus or crusty material in or around your eyes?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

13. Question about **CLOSING YOUR EYES:**

During a typical day in the past week, **how often** did your eyes bother you so much that you wanted to close them?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently

**4** Constantly

(page 3)

14. Question about **ARTIFICIAL TEAR USE:**

During a typical day in the past week, **how often** did you use artificial tears?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

15. Are you currently taking any of the following medications?

| | Yes | No |
|---|---|---|
| a. Thyroid medications .................................................................... | **1** | **2** |
| b. Blood pressure medications ......................................................... | **1** | **2** |
| c. Diabetes medications .................................................................. | **1** | **2** |
| d. Diuretics ........................................................................................ | **1** | **2** |
| e. Arthritis medications .................................................................... | **1** | **2** |
| f. Heart condition medications ....................................................... | **1** | **2** |
| g. Depression medications .............................................................. | **1** | **2** |
| h. Ulcer medications ........................................................................ | **1** | **2** |
| i. Oral contraceptives ....................................................................... | **1** | **2** |
| j. Antibiotics for acne or other skin conditions.............................. | **1** | **2** |
| k. Hormone replacement therapy ..................................................... | **1** | **2** |
| l. Allergy medications....................................................................... | **1** | **2** |

16. Question about **DRYNESS OF THE NOSE OR MOUTH:**

During a typical day in the past week, **how often** did you experience dryness of the nose or mouth?

**0** Never
**1** Rarely
**2** Sometimes
**3** Frequently
**4** Constantly

17. If you have used other dry-eye treatment(s), please note them down and describe their effectiveness:

___________________________________________________________________________

18. Have you been told you have dry eye(s)?

Yes No

19. Do you think you have dry eye(s)?

Yes No

# THANK YOU VERY MUCH!

## *Appendix III: Results from Dry Eye Questionnaire*

The response was graded from 0 to 4. The presence of ocular symptoms is taken as an indicative response and it is shown in the second column.

| Ocular symptoms | Number of responses recorded with a score greater than 2 |
|---|---|
| Grittiness | 10 |
| Burning/Stinging | 10 |
| Changing blur | 6 |
| Red | 12 |
| Watery | 6 |
| Eye crusting/mucus | 3 |
| General discomfort | 12 |
| Use artificial-tears eyedrops | 4 |
| Wanting to close eyes | 3 |
| Dry mouth or Nose feeling | 9 |
| Wear contact lens | 2 |

## *Appendix IV: Data from UV measurements*

UV data was measured by handheld radiometer over the period of GCAS course. The Spectroline DRC 100× digital radiometer, is made by Spectronics (Westbury, NY).

Relative transmittance of filter shows that filters are wavelength specific. Filter Fb was most effective at blocking out 300nm wavelength.